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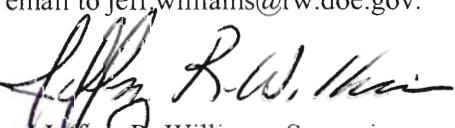
YUCCA MOUNTAIN - REQUEST FOR ADDITIONAL INFORMATION- SAFETY
EVALUATION REPORT, VOLUME 3 - POSTCLOSURE CHAPTER 2.2.1.3.2,
MECHANICAL DISRUPTION OF ENGINEERED BARRIERS, 2ND SET -
(DEPARTMENT OF ENERGY'S SAFETY ANALYSIS REPORT SECTION 2.3.4)

Reference: Ltr, Sulima to Williams, dtd 11/5/2009, "Yucca Mountain – Request for Additional Information – Safety Evaluation Report, Volume 3 – Postclosure Chapter 2.2.1.3.2, Mechanical Disruption of Engineered Barriers, 2nd Set – (Department of Energy's Safety Analysis Report Section 2.3.4)"

The purpose of this letter is to transmit the U.S. Department of Energy's (DOE) response to one (1) of the eight (8) Requests for Additional Information (RAIs) identified in the above-referenced letter. The response to RAI Number 6 is provided as an enclosure to this letter. DOE submitted the responses to RAIs Numbers 1, 2, 3, and 8 from this set on November 24, 2009 and plans to submit the remaining RAIs from this set on or before December 18, 2009.

The DOE references cited in the RAI response have previously been provided with the License Application.

There are no commitments in the enclosed RAI response. If you have any questions regarding this letter, please contact me at (202) 586-9620, or by email to jeff.williams@rw.doe.gov.



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OTM: CJM-0134

Enclosure:

Response to RAI Volume 3, Chapter 2.2.1.3.2, Set 2, Number 6



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RAI Volume 3, Chapter 3.2.2.1.3.2, Second Set, Number 6:

Demonstrate that two-dimensional representations of the waste package in dynamic load calculations do not underestimate significantly the potential for tensile tearing from seismic events.

Basis: DOE uses a two-dimensional plane strain representation of the waste package and its components for dynamic analyses under rubble loads (SNL, 2007, p. 6-216). This simplification assumes that the waste package extends infinitely in the direction normal to the calculation plane and that the structural response of the waste package is not affected by its boundaries. DOE compared results of two-dimensional and three-dimensional stress analyses (SNL 2007ap, Appendix D), using uniform static loadings that are not representative of the dynamic loads associated with seismic events. Because of the dynamic loading associated with seismic events and the higher rigidity of the lid area, the area of the waste package lid potentially could be more susceptible to tensile tearing than an open cylinder.

1. RESPONSE

The DOE uses a two-dimensional analysis in a plane perpendicular to the drift axis to approximate the structural response of a waste package surrounded by rubble (SNL 2007, Section 6.5.1.2). The two-dimensional, plane strain approximation treats the represented objects (waste package and rubble blocks) as though they extend infinitely in the out-of-plane direction (i.e., normal to the plane of analysis). As currently designed, the transportation, aging, and disposal (TAD)-bearing waste package extends approximately 2.9 meters in the out-of-plane direction (the nominal length of the TAD-bearing waste package is 5,850.1 mm (SNL 2007, Table 4-2)) and the rubble block size in the out-of-plane direction is of the same order as in the plane of analysis, 0.1 meters to 0.3 meters (BSC 2004, Section 6.4.1.1).

The DOE chose the two-dimensional, plane strain representation for the waste package because it overestimates structural deformation and strain in the outer corrosion barrier (OCB) relative to a fully three-dimensional representation. The lids at both ends of a waste package provide significant structural rigidity in comparison to the two-dimensional model, which represents the OCB as a ring of Alloy 22. The external forces on a ring in a two-dimensional, plane strain representation are only supported by hoop strains within the ring, while the mid-plane of the actual waste package will get significant structural support from the axial bending moments generated by the lids at the ends of the waste package in addition to the hoop strains. It follows that structural deformation and strain are maximized by the two-dimensional, plane strain representation for the OCB.

In this situation, the two-dimensional, plane strain representation overestimates the potential for tensile failure of the OCB, irrespective of the nature of the load. Alloy 22 is very ductile material that may rupture when strain exceeds a threshold of 28.5% (SNL 2007, Appendix A.2). (Note: When failure in the tensile mode is mentioned here, “rupture” and “tearing” are used interchangeably.) The analyses documented in *Mechanical Assessment of Degraded Waste Packages and Drip Shields Subject to Vibratory Ground Motion* (SNL 2007, Appendix D)

demonstrate that this strain threshold is exceeded only when the OCB collapses as a result of wall buckling. This conclusion is independent of the quasi-static or dynamic nature of the loading because it is based on geometric considerations alone (i.e., the strains in Alloy 22 are functions of deformation of the OCB). In other words, any dynamic load history and load distribution will not cause tensile rupture of the Alloy 22 unless it causes collapse of the OCB due to buckling. When the OCB collapses, the largest strains are in the middle of the waste package, away from the lids. Because the two-dimensional, plane strain approximation underestimates the collapse load (SNL 2007, Appendix D), it thereby overestimates the potential for tensile failure of the Alloy 22, irrespective of the static or dynamic nature of the load.

The two-dimensional model also maximizes the nonuniformity of rubble loads relative to a fully three-dimensional representation. The two-dimensional model assumes that the load from a rubble particle in contact with the OCB is a constant line load in the out-of-plane direction. The distribution and magnitude of the loads are expected to change along the axis of the waste package. The length scale over which the rubble load changes is approximately 0.2 to 0.3 m, much smaller than the waste package length or diameter (nominal outer diameter of the TAD-bearing waste package is 1,962.8 mm (SNL 2007, Table 4-2)). The variability of the three-dimensional loading from the rubble tends to produce a more uniformly distributed loading on the waste package, rather than constant line loads in the axial direction. The line loads in the two-dimensional approximation therefore overestimate the nonuniformity of the rubble load on the waste package and the associated magnitude of the deformation and strain in the OCB (SNL 2007, Section 6.5.1.2).

These concepts are confirmed by the comparison of two-dimensional and three-dimensional structural analyses for the waste package in Appendix D of *Mechanical Assessment of Degraded Waste Packages and Drip Shields Subject to Vibratory Ground Motion* (SNL 2007). This study directly considered alternate failure modes for the waste package and concluded that the two-dimensional representation underestimated strength and stiffness, and therefore did not underestimate the potential for tensile tearing from seismic events:

The two-dimensional waste package representation underestimates the strength and stiffness of the true three-dimensional waste package structure. This is because the three-dimensional structure has a finite length and diameter (approximately 5.8 m and 1.9 m respectively), and lids on both ends. Although there are modes of failure in the lids and the connections between the lids and the wall that can occur before failure of the outer corrosion barrier (OCB) in the middle cross section, these are ignored in the two-dimensional representation of the OCB. Further, some states of deformation in the middle of the OCB, which do not exceed the rupture strain and stress, could result in failure of the OCB at the connections between the wall and the lids and/or failure (or popping) of the lids. Results presented below explore these other modes of failure and show that the two-dimensional representation is weaker than the three-dimensional representation. (SNL 2007, Appendix D, first paragraph)

The analyses show that both the two- and three-dimensional representations of the OCB collapse at a certain load level as a result of wall buckling. The two-dimensional representation underestimates the collapse load between 3.5 and 6 times (SNL 2007, Table D-1). Before the OCB collapses, strains throughout the OCB are much smaller than the rupture strain for Alloy 22 (SNL 2007, Figures D-2 and D-4), irrespective of the (two- or three-dimensional) representation. After the OCB collapses, strains exceed the rupture strain only in the middle of the waste package, away from the lids.

For example, Figures D-2 and D-3 in *Mechanical Assessment of Degraded Waste Packages and Drip Shields Subject to Vibratory Ground Motion* (SNL 2007) show that maximum deformation and maximum stress concentrations occur towards the center of the waste package, and not in the lid area. This is physically reasonable because the central cross-sectional area of the waste package is much less stiff than the lid area, and therefore experiences the maximum deformation and maximum strain, as discussed above. The relative stiffnesses of the mid-plane versus the ends of the waste package are a function of the structure, and are relevant for both quasi-static loading and the dynamic loading during a seismic event.

Although the computational study in *Mechanical Assessment of Degraded Waste Packages and Drip Shields Subject to Vibratory Ground Motion* (SNL 2007, Appendix D) is based on quasi-static loads, the seismic damage abstractions for a waste package surrounded by rubble are based on fully dynamic calculations for 17 ground motions at 4 peak ground velocity (PGV) levels with two OCB thicknesses (SNL 2007, Section 6.5.1.3). In other words, the quasi-static approach has been used to evaluate the conservatism of the two-dimensional, plane strain representation relative to a three-dimensional representation, but is not used in the final damage calculations, which are fully dynamic, or in the subsequent analysis of the potential for tensile tearing during a seismic event.

In summary, the DOE chose the two-dimensional, plane strain representation for the waste package because it overestimates structural deformation and strain in the outer corrosion barrier (OCB) relative to a fully three-dimensional representation. This overestimate is attributable to the two-dimensional model that maximizes deformation and strain at the mid-plane of the waste package (and takes no credit for the support provided by the lids at the ends of the waste package) and maximizes the nonuniformity of rubble loads relative to a fully three-dimensional representation. The dynamic loads associated with seismic events will not change these observations because the relative stiffnesses of the mid-plane versus the ends of the waste package are a function of the structure, and applicable to both quasi-static and dynamic loading. Because the seismic damage abstractions for a waste package surrounded by rubble are based on fully dynamic calculations for seismic ground motions at 4 PGV levels, a two-dimensional representation of the waste package does not underestimate significantly the potential for tensile tearing from seismic events.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2004. *Drift Degradation Analysis*. ANL-EBS-MD-000027 REV 03. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20040915.0010; DOC.20050419.0001; DOC.20051130.0002; DOC.20060731.0005; LLR.20080311.0066.

SNL (Sandia National Laboratories) 2007. *Mechanical Assessment of Degraded Waste Packages and Drip Shields Subject to Vibratory Ground Motion*. MDL-WIS-AC-000001 REV 00. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20070917.0006.